DESIGN CONSIDERATIONS FOR THE INSTALLATION OF GROUND WATER RECOVERY TRENCHES

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Abstract. The use of trenches for the recovery of shallow groundwater is often more feasible then individual extraction wells. Trenches have the advantages of having a large surface infiltration area which minimizes plugging of the filter pack, a contiguous capture area which allows for a greater percentage of capture and lower operation cost since fewer pumps are required to span long linear areas.

Use of Trenches

The two most popular methods for the recovery of shallow contaminated ground water are the use of wells and infiltration trenches. Ground water recovery trenches typically consist of a narrow sand-filled trench, often with a collection lateral used to convey the water infiltrated to a sump where it is pumped to a treatment unit. Although the use of wells is more common, there are many situations where trenches would provide a more effective and economical means for recovering contaminated ground water.

Although trenches have been used to dewater soils since before the turn of this century, recent innovations in equipment designed for installing trenches with collection laterals and the ever increasing need to pump contaminated ground water for extended periods of time has prompted a new interest in the use of trenches in hydrogeologic settings where the contaminated water is at relatively shallow depths.

Trenches have proven to provide long-term effectiveness in the removal of both aqueous phase contamination and for light non-aqueous phase liquids (LNAPLs, i.e., floating products). In hydrogeologic settings where trenches are feasible, i.e., ground water is relatively shallow, trenches have several advantages over recovery wells including: (1) A much larger surface infiltration area providing lower ground water entrance velocities which extends the life of the recovery system in environments where plugging of the filter pack with fines may be a factor, (2) A more contiguous capture area compared to wells which rely upon the proper spacing for capture of migrating ground water, (3) Lower operation and maintenance cost of pumping equipment since a single sump pump can be utilized to recover ground water for hundreds of linear feet

Trench Depths and Effective Ground Water Capture Depths

Although there is heavy equipment available such as articulating backhoes and trackhoes capable of excavating to depths well in excess of 20 feet, and draglines much deeper, the depth is often limited to the cohesive properties of the soil, i.e., the ability of the soils to hold the trench open. The trench depth, of course, must extend beyond the water table which is often in the zone most likely to collapse during the excavation.

If the open trench method is used where the walls are removed and the opening assumes a "V" shape, a slope of at least 2:1 is recommended to ensure the stability of the excavation during placement of the lateral and filter pack. A drawback to this technique is the volume of soil required to be removed to attain even modest depths. At a slope of 2:1 a trench 15 feet deep would require an opening of 60 feet across yielding approximately 17 cubic yards of excavated soil for every linear foot of trench. It should also be noted this soil is usually contaminated and may require special health and safety provisions and possibly disposal requirements. Drag boxes have been successfully used to hold the excavation open while the lateral and sand pack are installed. This method greatly reduces the volume of excavated material.

Large trenching machines, resembling a Ditch-Witch™ have been used for many years to dewater soils to shallow depths. These trenching machines have demonstrated to be a valuable tool for use at contaminated sites. The trenching machine has the capability of cutting a narrow trench, laying the collection lateral and sand pack all in one step. Advantages include speed, uniform depth and filter pack placement, and health and safety aspects relating to the small volume of soil generated and that it is not necessary to place workers in the bottom of the trench. Disadvantages include depth limitations to usually on the order of 15 to 25 feet, use in moderately soft soils and the relatively high cost for trenches of short length.

The ground water capture effectiveness of a trench is directly related to the ratio of saturated zone dewatered compared to the total thickness of the water table aquifer. At a minimum a trench must be capable of lowering the water table 50 percent of the saturated thickness of the uppermost water bearing unit. Therefore, the minimum trench depth (level which water level can be lowered) should be at least the depth to the water table plus one-half the saturated thickness of the upper water bearing zone (Figures 2 and 3). Generally, the practical depth limitations for trenches are static water levels of 15 feet or less and depth to base of the aquifer of 40 feet or less. The minimum trench depth (TD_{min}) may be expressed as:

$$TD_{min} = SWL + ½ \text{ (Saturated Thickness)}$$

where:

Td_{min} = Minimum Trench Depth

SWL = Depth to static water level
Saturated Thickness=Saturated thickness of upper water bearing zone

Upgradient and Downgradient Capture Areas

The volume of water (Q) passing through an aquifer for a given length perpendicular to the flow direction (L_a) is equal to:

$$Q = T x i \ x L$$

where:
Q = volume of water flowing between two given points (gal/day)
T = transmissivity (gallons per day per foot)
i = natural ground water gradient (dimensionless)
L = length perpendicular to flow direction (feet)

The capture width (W) of a recovery trench for the water moving downgradient towards the trench is equal to the above volume of water plus a wider area along the edges as defined by:

$$W = \frac{Q_T}{T \times i} + L_t$$

where:
W = the capture width on the upgradient side of the trench (feet)
Q_T = volume water pumped from the trench (gallons/day)
T = transmissivity (gallons per day per foot)
i = natural ground water gradient (dimensionless)
L_t = length of trench (feet, same as L in above equation)

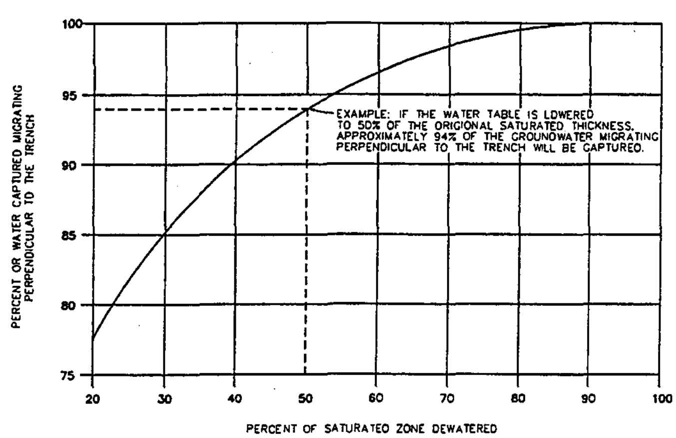

Figure 1. Recovery trench depth vs. capture effectiveness.

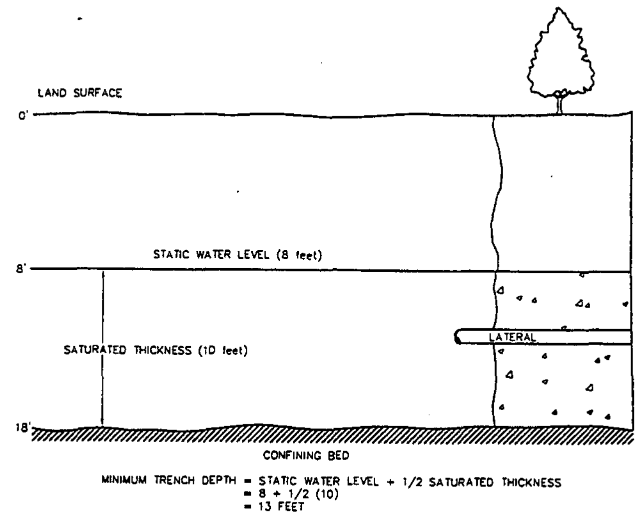

Figure 2. Minimum trench depth

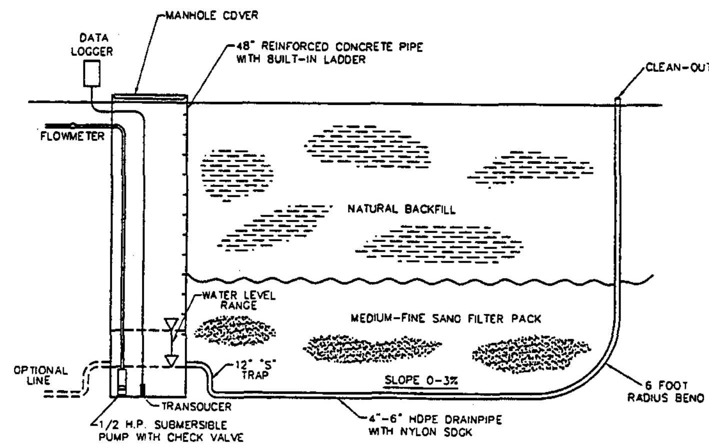

Figure 3. Typical recovery trench design

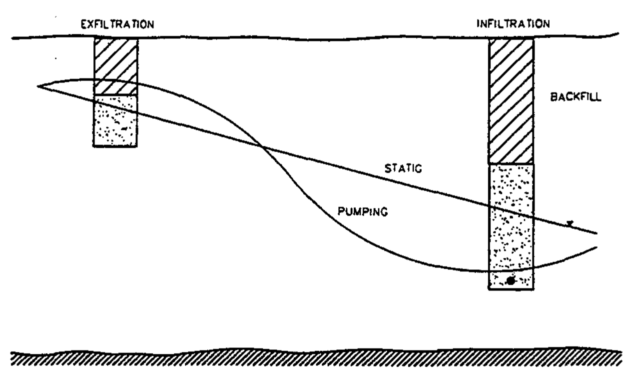

Figure 4. Exfiltration trenches for disposal of treated water and flushing of contaminated sediments.

During the initial start-up of the trench there will be an initial volume of water in storage (S) which will need to be removed to create the cone or envelope of depression. The volume is equal to the effective pore volume of the area dewatered. This excess water must be accounted for in determining the initial pumping rates.

Selection of Filter Pack Material

The most important factor to ground water capture effectiveness and life of the trench is the selection of the material selected for use in the filter pack placed between the natural sediments and the collection lateral. One of the most common mistakes is to use too large of a filter pack material such as crushed rock or gravel. Fine grained sediments of the formation will tend to migrate between the "large" filter material and plug the filter pack.

Since the rate of ground water flow into a trench is relatively slow, commonly less than a few feet per day, the limiting factor is usually the hydraulic conductivity of the formation. It is recommended that representative samples of the lower portion of the saturated formation material, adjacent to the lateral, be sampled and sieve analyses run to determine the grain size distribution. Selection of a filter pack material comprised of a clean washed fine quartz sand close to the mean grain size of the formation material or slightly larger is recommended. The permeability of any clean fine quartz sand will usually be many times greater than the formation. Exceptions would be formations comprised of clean sands and gravels which would require a larger mean grain size diameter filter pack. Care must be taken to ensure that the filter pack material is larger than the openings on the nylon filter sock fitted around the collection lateral. A minimum of 6 inches of filter pack material are recommended below and beside the lateral to separate the formation from the collection lateral. The height of the sand pack may extend any length above the lateral, however, the depressed water level at steady state will most likely be only a few feet above the lateral. Extending the filter pack to the static water level is generally not necessary. The use of geomembranes are generally not necessary and may cause plugging if not selected or installed properly.

Installation of the Collection Lateral

Although it is not absolutely necessary to install a collection lateral in the filter pack material, it is highly recommended for a number of reasons. The lateral is much less likely to "plug" as compared to the filter pack without the lateral. If a small section of the filter pack were to plug with clay size particles or bacterial growth, the ability of the filter pack to transmit ground water to the sump would be greatly impaired and the effectiveness of the "outer" areas of the trench may be impacted. The installation of a collection lateral allows for access of the filter pack if the collection lateral is constructed in a manner to provide access at land surface at the terminal away from the sump. Access would allow physical and/or chemical rehabilitation of the lateral if a decline in effectiveness of the filter pack is observed.

Another advantage of a collection lateral is the installation of an "S" trap to keep the lateral constantly saturated (Figure 3). It is important not to entirely dewater the filter pack in order to minimize the potential for bacterial (algae) growth in the filter pack. Maintaining saturated conditions has proven to be effective in minimizing plugging due to bacterial growth and volatization of aromatics which help keep the semivolatiles from becoming viscous and plug the filter pack.

If the land surface changes elevation greatly along the length of the lateral, provisions must be made to try to maintain a level or low slope during construction of the lateral in order that the entire length of the lateral remains submerged. Even slight slopes over long distances will cause the far end to most likely extend above the depressed water level.

Operation and Maintenance

Very little maintenance is required for a properly constructed infiltration trench system. A large diameter sump is recommended to provide ample storage of water to minimize cycling of the sump pump. A 3- or 4-foot diameter reinforced concrete pipe with manhole cover and built-in ladder has proven to be useful. On-off levels for the pump can be set with float switches or transducers calibrated to measure water levels. Transducers with data loggers have a high degree of flexibility and eliminate the need to physically enter the sump. Data loggers can also store water level data, and flow rates and be remotely operated using phone lines. Computerized data can be downloaded or pumping levels changed remotely without visiting the site.

Floating products can also be removed using a dual phase pump in the sump. A skimming pump for the LNAPLs and a lower pump to drawdown the water level has proven to be an effective configuration. If LNAPLs are anticipated, the filter pack should also be hydraulically connected into the sump for product to enter.

Exfiltration trenches (Figure 4), normally constructed of a shallower depth can be effectively used to discharge treated water upgradient. This flushing action serves to accelerate the cleanup time for affected soils between the trenches.

Monitoring Trench Effectiveness

Monitoring of the trench effectiveness is usually performed by the placement of piezometers perpendicular to the axis of the trench. Spacings between the piezometers should be logarithmic in distance depending upon the transmissivity of the formation material. Generally five to seven piezometers across the trench, per 200 linear feet of trench, are sufficient. Location of the piezometers should include one in the filter pack material, one each 10 feet up and downgradient of the trench, and additional piezometers at 25 and 75 feet upgradient perpendicular to the trench. Water levels should be monitored during the start-up of the trench to monitor dewatering of the formation near the trench and to determine when steady state pumping levels are attained. Once steady state is attained water levels should be monitored at least quarterly to assess the efficiency of the trench and ensure that plugging of the filter pack is not occurring.

Summary and Conclusion

Ground water recovery trenches have proven to be a highly effective and cost-efficient method for recovering a wide range of dissolved and LNAPL contaminants from the subsurface. Trenches are particularly applicable in shallow aquifers where water tables are generally less than 15 feet and base of the aquifer is less than 40 feet. Trenches are easily maintained and operational costs are generally lower than using multiple wells for ground water recovery.